

JET AIRCRAFT CONNECTOR RELIABILITY REPORT

AMPHENOL

ENVIRONMENT-RESISTANT CONNECTOR
FIELD RELIABILITY REPORT

AMPHENOL-BORG ELECTRONICS CORPORATION
Chicago 50, Illinois

Summation of Report No. RC3-008 - dated 15 May, 1963

INTRODUCTION

Connector reliability has always been cause for concern in the aircraft industry. Until this time no significant field failure reporting was carried on. This report involves data originated by several major domestic and international trunk carriers. The raw data was supplied to the Transport Division of the Boeing Company and concerns Boeing 707 and 720 Jet aircraft.

Connector installation and location data was furnished to the Engineering Service Analysis-Reliability Unit by various engineering departments of the Transport Division.

The data was gathered from airline maintenance sources in the field. Connector types are divided according to the military specifications to which they conform performance-wise.

Significant failure rates for the military specification types are as follows:

MIL-C-5015	1.34	per	million	connector	hours
MIL-C-26482	.172	"	"	"	"
MIL-C-26500	.049	"	"	"	"

The report narrative, data arrangement and calculations, and the conclusions reached are the work of Messrs. James E. Atkinson, Director of Reliability, and Hugh C. Edfors, Reliability Engineer of the Amphenol Connector Division of Amphenol-Borg Electronics Corporation.

CONNECTOR RELIABILITY
BASED ON ACTUAL FIELD MEASUREMENTS

One of the areas of extreme importance in regard to connector reliability which, to the best knowledge of the authors at least, has never been significantly investigated and reported upon, is the area of connector field failures.

About a year ago, however, the Amphenol Connector Division Reliability Department was privileged to read a report from the Boeing Company, Transport Division, which contained a wealth of data on connector field failures. This data was reported by a number of major domestic and international airlines employing 707 and 720 type jet aircraft. It covered hundreds of thousands of flight hours, thousands of departures and millions of connector operating hours.

After very careful study, it was concluded that the report was indeed significant; however, it appeared that many more specific facts, especially with regard to the exact environmental experiences suffered by each connector, would be necessary before the value of the data could be fully realized.

Accordingly, one of the co-authors of this paper, Mr. Hugh Edfors of Amphenol's Reliability Research and Development Section, was assigned to the Boeing Transport Division plant in Renton, Washington, where, with the help and cooperation of Boeing's Engineering Service Analysis-Reliability Unit and other Engineering Departments, he was able to gather the facts necessary to produce this report.

At Boeing, much additional data was discovered as having been reported subsequent to the original report. When all data was totaled it

amounted to 437,267 in-flight hours, 192,929 take-offs and landings, and 416,371,952 connector operating hours. This data was reported on a total of 173 aircraft of which 133 were Boeing 707's and 40 were Boeing 720B's.

Connectors used on the 707 and 720 aircraft can be sub-divided into types conforming performance-wise to military specifications as is shown in the following table:

Aircraft	Number of MIL-C-5015 Types	Number of MIL-C-26482 Types	Number of MIL-C-26500 Types	Non-Spec & Rack & Panel Types
707	270	245	274	189
720	426	230	108	100

Many of these connectors are connected and very seldom disconnected thereafter while others are disconnected and re-connected many times during regular maintenance programs, and in trouble-shooting.

Connectors are located all over the aircraft and, consequently, are subjected to a widely varied set of environmental circumstances. Since the study was premised on interpretation of connector data under like environmental circumstances, the first job to be accomplished was to distinguish areas of the airplane where environments could be identified as similar. This resulted in identification of environmental areas I through VIII as shown in Figure 1.

ENVIRONMENTS - OTHER CONTRIBUTIONS TO FAILURE

<u>Group</u>	<u>Location</u>	<u>Shock</u> Max. Nominal	<u>Vibration</u>	<u>Temperature</u> Degrees F	Sources of Contamination	<u>Other Factors</u>
I	Fuselage & Tail	Forward 4 G's 2.7 G's C. G. 5 G's 3.3 G's Aft 6 G's 4 G's	5 CPS to 1000 CPS 0.08 D.A. Maximum	-65 to 175 - Soak* -50 to 110 - Operating	Moisture & Dust	Frequent Mating & Unmating Connector Inaccessibility in Specific Limited Areas
II	Wings, Struts & Wheel Wells	10 G's 5 G's (At Wing-Tips)	5 CPS to 1000 CPS 0.08 D.A. Maximum	-50 to 200	Moisture & Dirt Hydraulic Fluid & Jet Fuel as a result of leakage	Connector Inaccessibility in Specific Limited Areas
III	Landing Gear	5 G's	5 CPS to 300 CPS 0.036 D.A. Maximum	-50 to 300	Moisture & Dirt Hydraulic Fluid as a Result of leakage	Cable whip due to landing shock
IV	Engine Nacelles	Outboard 9 G's 6 G's Inboard 6 G's 4 G's	5 CPS to 1000 CPS 0.08 D.A. Maximum	200 to 367	Moisture Hydraulic Fluid & Jet Fuel as a Result of Leakage Engine Oil as a Result of Servicing	Maintenance Handling Connector Inaccessibility
V	Engine Accessory Area	Outboard 9 G's 6 G's Inboard 6 G's 4 G's	5 CPS to 1000 CPS 0.08 D.A. Maximum	250 to 340 Ambient 380 to 400 Starter	Moisture Hydraulic Fluid & Jet Fuel as a Result of Leakage Engine Oil as a Result of Servicing	Connector Inaccessibility

VI	Engine Nose Dome	Outboard 9 G's 6 G's Inboard 6 G's 4 G's	5 CPS to 1000 CPS 0.08 D.A. Maximum	190 Maximum	Moisture	
VII	Rear Engine Firewall	Outboard 9 G's 6 G's Inboard 6 G's 4 G's	5 CPS to 1000 CPS 0.08 D.A. Maximum	300 Cruise 400 - Climb (30 minutes) Forward of Fire- wall	Moisture Hydraulic Fluid & Jet Fuel as a Re- sult of Leakage Engine Oil as a Re- sult of Servicing Extreme High Ve- locity Exhaust Gases	
VIII	Nacelle Strut Firewall	Outboard 9 G's 6 G's Inboard 6 G's 4 G's	5 CPS to 1000 CPS 0.08 D.A. Maximum	320 to 390	Moisture Hydraulic Fluid & Jet Fuel as a Re- sult of Leakage Engine Oil as a Re- sult of Servicing	Engine Change Point Frequent Mainte- nance

* Entire Aircraft

Figure I

It is extremely interesting to note that three major failure modes evolve in this study, namely:

1. Termination failure modes, including:
 - a) Defective contacts.
 - b) Bare, loose, or broken wires.
 - c) Cold solder joints.
2. Failure modes involving improperly seated connectors and including specific failures as:
 - a) Loose connectors.
 - b) Disconnected connectors.
 - c) Mismatched connectors (pushed back pins).
3. Failure modes involving contamination, such as:
 - a) Shorts caused by dirt or moisture.
 - b) High contact resistance due to dirt in a contact pair.

It is also interesting to note the many instances where the incidence of failure is dictated by the circumstances under which the connectors operated. For example, termination failures in the landing gear where cable shock is an extremely severe environment is 57% of the failure from all causes. Contamination failures in the rear firewall of the engine where high velocity exhaust gases as well as dirt and soot are prime contributors to this mode of failure is 68% of the failures from all causes.

This study and data correlation leads to some basic conclusions on connector field reliability under circumstances associated with

commercial jet aircraft. These are worth enumeration and further comment.

1. Connectors are, in general, able to compare with other components from the standpoint of failure rate.

Typical failure rates quoted for high reliability components are *:

Ceramic Capacitors	0.02/million hours
Diodes	0.564/million hours
Wire Wound Resistors	0.087/million hours
Power Relays	0.3/million cycles
Germanium Power Transistors...	0.6/million hours

If one compares the above failure rates with the overall failure rate for connectors of 0.62 failures per million hours or with the failure rate of 0.048 per million hours for MIL-C-26500 type connectors ** (See Chart I), the validity of this conclusion is substantiated, and the statement that "system reliability can be greatly enhanced by removing connectors" can be seen to be unwarranted for high performance connectors.

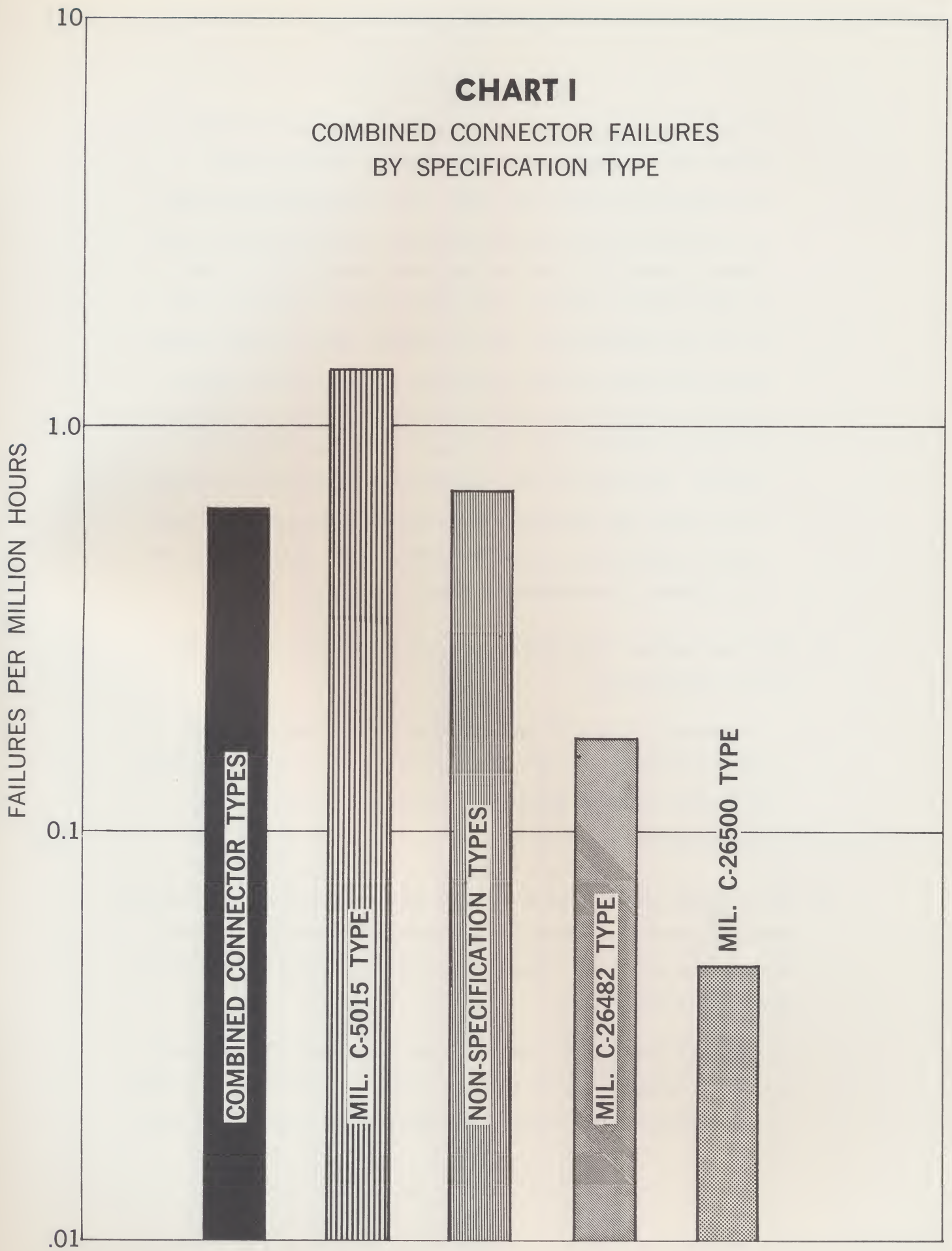
2. Failure modes for connectors are dictated by the environments they see, and proper cooperation between the systems engineer and the connector application engineer can materially reduce the failure rate for any given set of environmental circumstances, and, consequently, for any connector application.

* D. R. Earles & M. F. Eddins - Reliability Physics (The Physics of Failure) Proceedings; 9th National Reliability Symposium.

** Both figures are based on failures causing departure delays of aircraft.

CHART I

COMBINED CONNECTOR FAILURES BY SPECIFICATION TYPE



As an example, attention is directed to Chart II which shows the incidence of failures due to contamination throughout the entire aircraft. Note that the failure rate is in proportion to the effectiveness of the connector seal. Those connectors conforming performance-wise to MIL-C-5015 exhibit a failure rate about eleven times as great as those conforming to MIL-C-26482, which is the middle-most effectively sealed connector. MIL-C-26482 types exhibit a failure rate which is about 3.8 times as great as MIL-C-26500 types, which are the most effectively sealed. In terms of less maintenance, and less connector down time, the advantage to be gained from using the best sealed connectors, in applications where contamination is a problem, is consummately clear.

3. The mechanical crimp termination is vastly superior to the solder termination.

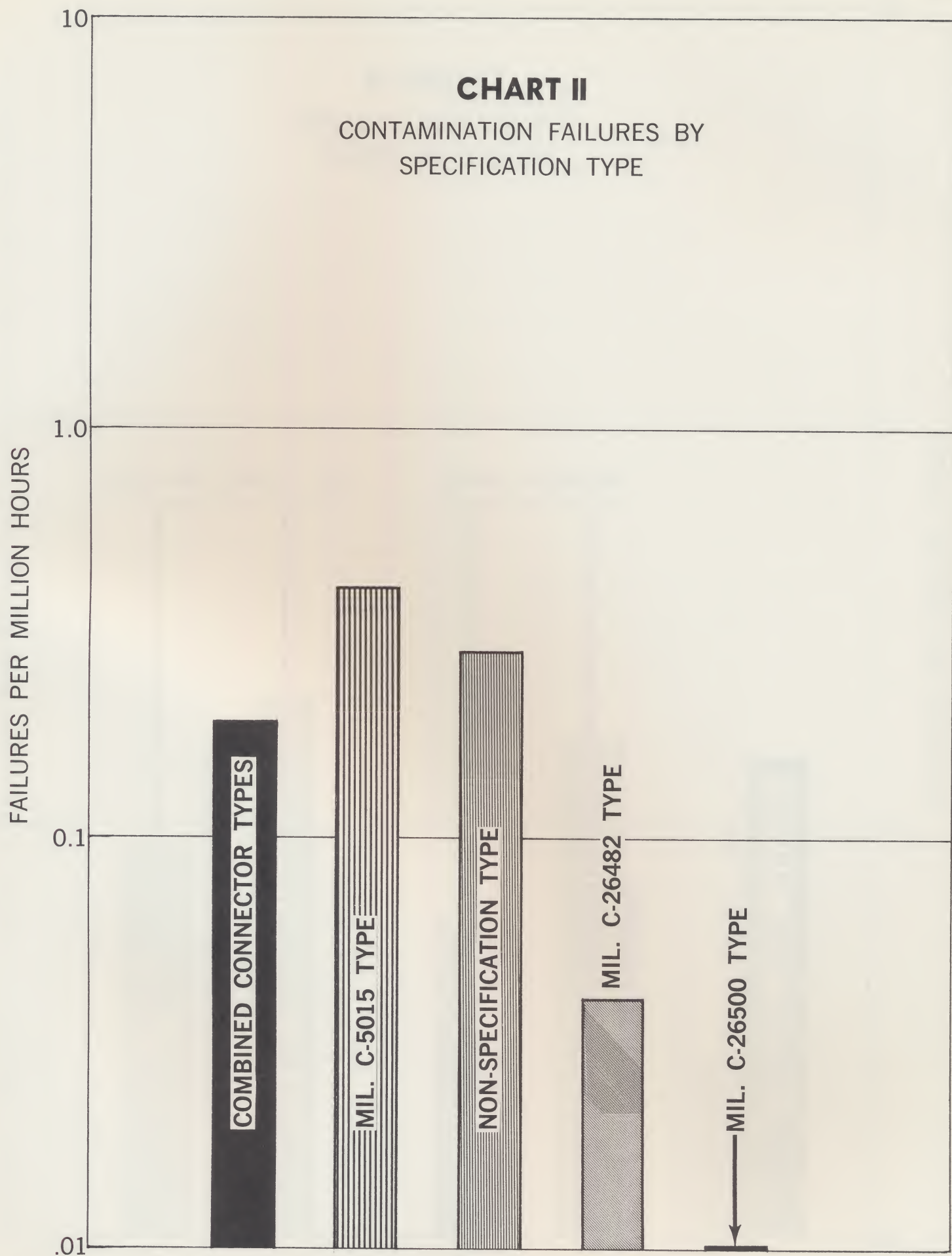
A glance at Chart III immediately reveals that the termination failure rate for the entire aircraft is approximately 2.5 times greater for solder termination than it is for crimp type.

4. It is entirely fallacious to assume that the more environmentally sophisticated connectors need necessarily give more trouble from a "human" error standpoint. In fact, just the opposite is true in this study.

Chart IV depicts the failure rates attributed to improperly seated connectors. It shows an actual failure rate of 0.289 failures per million hours for MIL-C-5015 type connectors.

CHART II

CONTAMINATION FAILURES BY
SPECIFICATION TYPE



FAILURES PER MILLION HOURS

10

CHART III

TERMINATION FAILURES

SOLDER VS. CRIMP

1.0

BROKEN WIRES

ALL TERM. FAILURES

0.1

COMBINED TERM. FAILURES

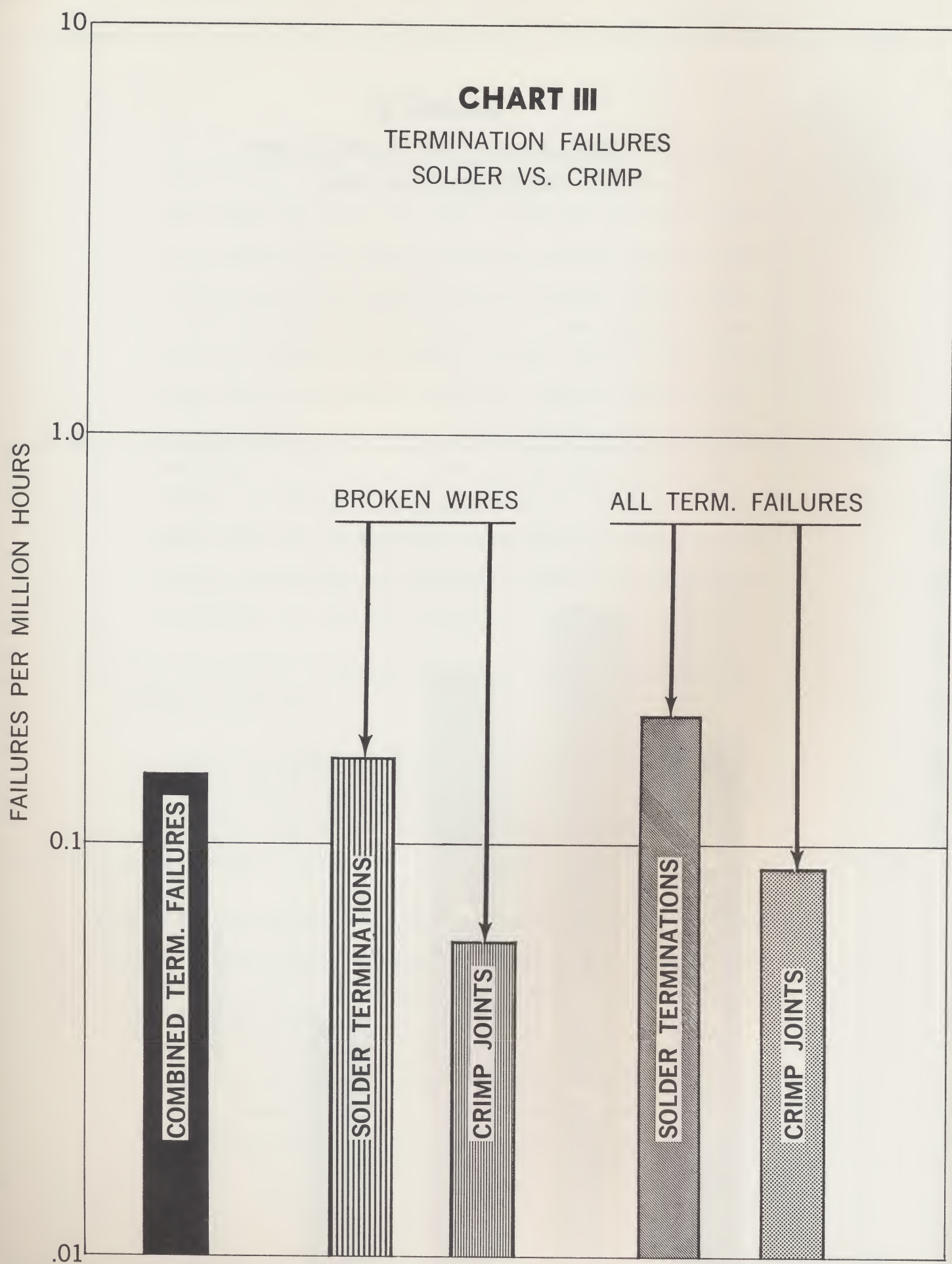
SOLDER TERMINATIONS

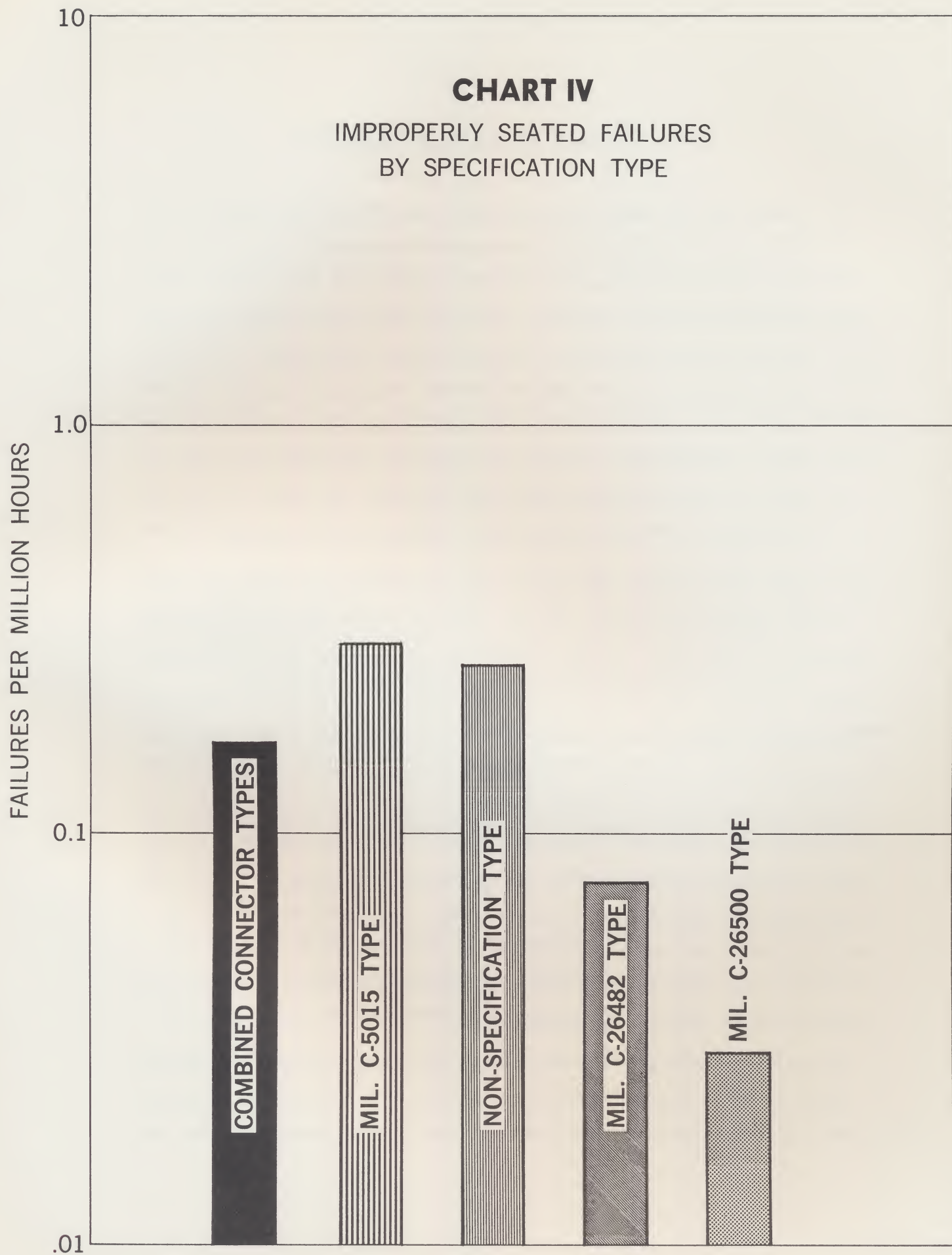
CRIMP JOINTS

SOLDER TERMINATIONS

CRIMP JOINTS

.01





These are the least sophisticated connectors, environmentally, of the three types shown. It shows a failure rate of 0.076 failures per million hours, or, approximately one-fourth the failure rate for the middlemost sophisticated connectors, namely those conforming performance-wise to MIL-C-26482. Finally, it shows a failure rate of 0.029 failures per million hours for MIL-C-26500 type connectors which are environmentally far more sophisticated than either of the other two types. It would certainly be misleading to suggest that this result is automatic, but the millions of operating hours involved offer irrefutable proof that properly trained and properly motivated maintenance personnel can successfully handle a high performance connector.

The authors believe that much good should come out of this study of connector field reliability. It should encourage the using and manufacturing industries for electrical connectors to greater cooperation in matters of connector application and to equally great effort in the field of training and motivation for personnel installing and maintaining electrical connectors. It should dispel ignorance and error by pointing out "use" reliability figures for aircraft application. And, perhaps most importantly, it should provide incentive for similar reports in other areas of application.

OUTLINE OF DATA REDUCTION

The original source data for field failure studies on connectors was the reports on failures causing departure delays of 707 and 720 aircraft made to the Transport Division of the Boeing Company by five domestic and international airlines. Copies of these reports go also to the Air Transport Association. The reports cover about half of the Boeing fleet of the types indicated and extend over an operating period of 11 months — January through November of 1962. Since this period, at least two additional airlines have begun to participate in the reporting system, so it is expected that useful updating of the various reports based on these originals can be accomplished in the future.

With the assistance of Boeing personnel, the failures were traced by use of the aircraft serial number and the verbal description of the cause of trouble as found in the failure report. The faulty connector was thus identified by Boeing equipment number, by connector manufacturer and by type. Exhibit I attached shows the compilation by Boeing of original failure data used as described above.

Failures according to Boeing equipment number were next arranged according to:

- a) Airplane section
- b) Number of failures per equipment number
- c) Failure modes per equipment number
- d) Connector manufacturer and type

Exhibit II attached shows this step in the data reduction. By correlating failure modes with similarity of environments in the aircraft, the data was grouped into eight different environmental-failure areas. The

eight areas are described in some detail in figure I of the preceeding report. Each of the eight groups were broken down into tables containing the following information:

- a) Boeing Equipment number
- b) Section and verbal description of exact location including station number and quantity of connectors for those aircraft reporting. This was found from Boeing electrical schematic books D6-7452 and D6-1941, aircraft section prints, and aircraft mock-up models inspected at the Boeing Seattle plant.
- c) Number of malfunctions were determined by equipment number and failure mode and assigned to the appropriate connector vendor according to aircraft serial number in which the failure or failures occurred.
- d) Total quantity of connectors represented by a vendor for each of the eight environmental areas was determined based on the work done in (b) and (c). Percentage failures was found by dividing total quantity of a vendor's connectors (by areas) into the total failures in that area. Exhibits III, IV, and V attached illustrate the procedures and results.

Relative failure mode percentages, (Termination failures, Improperly Seated, and Contaminated) were found by using the tables described above which contain failure modes by equipment number. A table was made up for each of the eight environments. Contained in each table are the cumulative failure totals for each of the three failure modes. A computation was made by dividing the total number of failures for a given area into each of the three sub-totals by major failure mode. Exhibits VI and VII attached are illustrative.

A choice was made at this point as to which of the three major military specifications for circular connectors (MIL-C-5015, MIL-C-26482, and MIL-C-26500) most nearly described the connectors under study. The choice was made, first of all, on performance parameters, and, secondly, on design parameters. Once this was accomplished, failure rates by individual environmental area and for the aircraft as a whole could be determined as described below.

Failure Rate Calculations per million hours were determined for each vendor's connector by knowing the following:

- a) Number of vendor's connector failures (for each specification type).
- b) Number of connectors per aircraft and the number in each environmental area.
- c) Total number of flight hours for the aircraft in the reporting period.

The failure rate is defined as the ratio of the number of failures in a given time period to the cumulative number of part hours during the same period. Since there is no discernable pattern of wear-out type failures, connectors are believed to fail randomly or according to a constant failure rate, (Exponential failure distribution).

To obtain the number of cumulative part hours, calculations were based on the number of connectors per plane times the total flight hours for 173 planes. Flight hours were actually divided between 707 and 720 model planes.

Failure rate calculations were performed for each environmental area using each vendor's connector and combining similar connectors by each military specification type. Additional calculations were

performed to obtain overall failure rates in the aircraft by individual vendor's connectors and by military type. Exhibit VIII attached described the method for Failure Rate Computation.

EXHIBIT I

The following sample sheet is indicative of the manner in which the data was accumulated and assembled as to mode, date, aircraft type and equipment number.

This information was taken directly from the delay reports submitted to Boeing Transport Division.

all 720

FAILURE MODE	DATE	AIRCRAFT	DELAY	REMARKS
?	6-11-62	D-148	C	ITEM: #1 EGT is inop. Its reads 900 most of the time. ACTION: Checked cannon plug connections and wire at cannon plug at eng. rear firewall and front engine connection also at eng. strut. Checked wire at spool and at rear of inst panel no interrupted circuit found.
DIRT	6-13-62	D-148C		ITEM: #3 EGT 20-30 low for same power settings, all else OK. ACTION: <u>Cleaned</u> cannon plugs on eng from thermocouple.
	6-12-62	X		ITEM: RM cabin compre RPM sways continually. ACTION: Repaired <u>loose</u> connection behind indicator.
	6-14-62	W		ITEM: Light out in #1 EGT gauge. ACTION: Repaired wire at instrument.
	6-11-62	W		ITEM: L/H anti-ice valve #1 engine is stuck in open position. ACTION: Changed shorted eng anti-ice harness (56-HA-201) checked valve operation OK.
DIRT	6-14-62	CX		ITEM: #4 res. tank reads 200 lbs when tank is empty. ACTION: Checked and <u>cleaned</u> all pins and plugs on front rt. spar and indicator reading normal now.
LOOSE	6-13-62	M-275		ITEM: #2 diffuser vibration inop. ACTION: <u>Tighten</u> cannon plug on detector pickup. Test OK.
LOOSE	6-15-62 D199	D-199C		ITEM: #4 enr. N2 RPM gage sticks ACTION: Checked and <u>tightened</u> conn on #4 N2 tach gen.
LOOSE	6-15-62 D559	D-559C		ITEM: Capt. Clock lite (rear) flickers. ACTION: Secured <u>plug</u> on clock.
LOOSE & DIRT	6-15-62	D-190C		ITEM: #4 CSD oil temp low. ACTION: <u>Cleaned and tightened</u> cannon plug at firewall.
DIRT & MOISTURE	6-15-62	D-190C		ITEM: #3 CSD temp indication is erratic. ACTION: Cleaned and blew out cannon plugs at temp bulbs, checked OK.
?	6-15-62	D-143	C	ITEM: #1 left reserve fuel quantity gauge inop. ACTION MIAMM Replaced cannon plug and indicator checked OK.

EXHIBIT II

The sample sheet following this page shows how the information delineated in Exhibit I was correlated with the section and location within the aircraft, number of malfunctions and the connector manufacturer.

Connector Number	Section	Location	Number of Malfunctions	Malfunction Modes	Connector Manufacturer
D-559	41		1	Loose	Not Known
D-568	41	Gen Loadmeter	1	Loose	Not Known
ED-62	41	AFC Transponder	1	Bent Pin; Wire Broken	DPD Cannon
ED-73	41	VHF Transmitter	1	Coaxial Contaminated	DPA Cannon
ED-131	41	Integrated Air Data	1	Loose	DPD Cannon
ED-301	41	Soran Indets	1	Broken Pins	DSG7 Deutsch
	41	Autopilot "J" Box	1	Burned Insulator (short)	DPA Cannon
ED-448	41	Interrogator DMKT 2	1	Contaminated	DPA Cannon
D-371	43	Cabin Air Thrust Valve, Sta. 600T	1	Broken	69 Asphendel
D-394	43	Main Cabin Air Duct Sensor, Sta. J-600	1	Broken	10-120 Bendix
D-397	43	Cont. Cabin Ambient Temp Sensor, Sta. 714	1	Loose	10-129 Bendix
D-468	43	L.H. Compressor Cont. Circuit	1	Replaced	10-129 Bendix
ED-352	43	Interphone Amplifier	1	Loose	69 Asphendel
ED-1751	43	Angle of Attack Sensor	1	Loose	Not Known

EXHIBIT III

At this point, the foregoing Exhibits I and II were further correlated to eight environmental areas outlined previously. For ease of reference a copy of this chart is included with the exhibit.

Note that it is here that the number of connectors involved in failures was tied down to each environmental area.

ENVIRONMENTAL Group I

Connector Number	Section	Location	NUMBER OF CONNECTORS	Number of Malfunctions	Malfunction Modes	Connector Manufacturer
D-80	41	Plug, Ind. Outside Ram Air Temp.	173	2	1 Reseated 1 Would not lock (Duncch)	VAIL
D-138	41	Plug, Ind. Oil Qty. Eng. 1 in P-11 Engineers Panel	692	6	1 Contaminated 2 Loose 1 Wire Broken 1 Loose and Contaminated 1 Required	165 AMPH (solds)
D-150	41	Plug, Ind. Res. Tank No. 1 in P-11 Engineers Panel		4	2 Moisture 1 Loose & Contaminated 1 Replaced	165 AMPH (solds)
THRU D-143	41	Plug, Ind. Fuel Qty. Ctr. Wing Tank in P-11 Engineers Panel	2595	3	1 Loose 1 Replaced 1 High Resistance	165 AMPH (solds)
D-46	41	Ind. Tach, Sta. 200, Panel P-9	692	1	High Resistance	69 Series
D-54	41	Ind. Oil Press, Sta. 270, Panel P-11	692	1	Repaired-bad connection	69 Series
D-73	41	Ind. Hyd. Oil Qty., Panel P-11	173	1	Loose	10-129 Bendix
D-85	41	Load Contr. Com. Drive, Sta. 328 Elec. Rack	692	1	Reseated	VAIL
D-135	41	Plug, Cont Cabin Programmer, Sta. 245	173	4	3 Loose 1 Loose & Contaminated	PROFE Bendix (solder)
D-321	41	Recept., External Power Lower 51 Section	346	3	1 Maintenance Error 1 Bent Pins in Power Plug 1 Corroded Receptacle	(Drove GYS away) VAIL
D-374	41	Tech. Ind.	692	1	Broken Wire	69 AMPH

ENVIRONMENTS - OTHER CONTRIBUTIONS TO FAILURE

<u>Group</u>	<u>Location</u>	<u>Shock</u> Max. Nominal	<u>Vibration</u>	<u>Temperature</u> Degrees F	<u>Sources of Contamination</u>	<u>Other Factors</u>
I	Fuselage & Tail	Forward 4 G's 2.7 G's C. G. 5 G's 3.3 G's Aft 6 G's 4 G's	5 CPS to 1000 CPS 0.08 D.A. Maximum	-65 to 175 - Soak* -50 to 110 - Operating	Moisture & Dust	Frequent Mating & Unmating Connector Inaccessibility in Specific Limited Areas
II	Wings, Struts & Wheel Wells	10 G's 5 G's (At Wing-Tips)	5 CPS to 1000 CPS 0.08 D.A. Maximum	-50 to 200	Moisture & Dirt Hydraulic Fluid & Jet Fuel as a result of leakage	Connector Inaccessibility in Specific Limited Areas
III	Landing Gear	5 G's	5 CPS to 300 CPS 0.036 D.A. Maximum	-50 to 300	Moisture & Dirt Hydraulic Fluid as a Result of leakage	Cable whip due to landing shock
IV	Engine Nacelles	Outboard 9 G's 6 G's Inboard 6 G's 4 G's	5 CPS to 1000 CPS 0.08 D.A. Maximum	200 to 367	Moisture Hydraulic Fluid & Jet Fuel as a Result of Leakage Engine Oil as a Result of Servicing	Maintenance Handling Connector Inaccessibility
V	Engine Accessory Area	Outboard 9 G's 6 G's Inboard 6 G's 4 G's	5 CPS to 1000 CPS 0.08 D.A. Maximum	250 to 340 Ambient 380 to 400 Starter	Moisture Hydraulic Fluid & Jet Fuel as a Result of Leakage Engine Oil as a Result of Servicing	Connector Inaccessibility

VI	Engine Nose Dome	Outboard 9 G's 6 G's Inboard 6 G's 4 G's	5 CPS to 1000 CPS 0.08 D.A. Maximum	190 Maximum	Moisture	
VII	Rear Engine Firewall	Outboard 9 G's 6 G's Inboard 6 G's 4 G's	5 CPS to 1000 CPS 0.08 D.A. Maximum	300 Cruise 400 - Climb (30 minutes) Forward of Fire- wall	Moisture Hydraulic Fluid & Jet Fuel as a Re- sult of Leakage Engine Oil as a Re- sult of Servicing Extreme High Ve- locity Exhaust Gases	
VIII	Nacelle Strut Firewall	Outboard 9 G's 6 G's Inboard 6 G's 4 G's	5 CPS to 1000 CPS 0.08 D.A. Maximum	320 to 390	Moisture Hydraulic Fluid & Jet Fuel as a Re- sult of Leakage Engine Oil as a Re- sult of Servicing	Engine Change Point Frequent Mainte- nance

* Entire Aircraft

Figure I

EXHIBIT IV

The attached sample worksheet shows how the Boeing equipment number, the manufacturer, number of connectors involved, the manufacturer's series type number and the airplane environment were correlated.

EQUIPMENT NUMBER	MANUFACTURER	QTY	SEALING TYPE	OPERATIONAL COMMENTS
2945	Burndy 1.3 Series	1	MS30R-C4-2	Pressurized
2951	Burndy 1.3 Series	1	MS30R-C5-2TH	Pressurized
2952	Burndy 1.3 Series	1	MS30R-C4-2TH	Pressurized
2961	Burndy 1.3 Series	1	MS50P-M5-2	Pressurized
2962	Burndy 4.3 Series	1	MS50P-M4-2	Pressurized
3158	Leach	1	50-1001-92R	Wheel Well
RD3191	Boeing	1	BAC-A14V	Pressurized
RD3264	Boeing	1	BAC-P20AK	Pressurized
3561	VMIL	1		Pressurized
3562	VMIL	1		Pressurized
RD3723-3738	Boeing	10	BAC-J11B	Pressurized
3981	Bendix S	1✓	BP06E-12-10P	Pressurized
3991	Bendix S	1✓	BP00E-12-10S	Pressurized
RD4003-4004	Boeing	2	BAC-63	Pressurized
(4311)	Amphenol	x 4	84-16E14-7S	Pressurized ENG. NAC
(4321)	Amphenol	x 1	84-10E14-7P	Pressurized ENG. NAC
4381	Amphenol	1	84-16E14-19P	Pressurized /
4391	Amphenol	1	84-10E14-19S	Pressurized /
4451	Bendix S	1✓	BP06E-8-2S	Pressurized
4471	Bendix S	x 1✓	BP06E-8-3S	Wheel Well
4472	Bendix S	1✓	BP06E-8-3S	Wheel Well
4611	Bendix S	1✓	BP06E-16-26SX	Pressurized
5531	Amphenol	1	84-16E22-55P111	Pressurized
5533	Amphenol	1	84-16E22-55P	Pressurized /
5532	Amphenol	1	84-16E22-55P111	Pressurized /
5535	Amphenol	1	84-16E22-55P	Pressurized /
5536	Amphenol	1	84-16E22-55P-N1	Pressurized /

EXHIBIT V

Data from the worksheets indicated in Exhibit IV was then reduced to determine the connector manufacturer's series number and the number of connectors in each environmental area. This data, versus the total number of connectors represented, provided the failure percentage by connector manufacturer's series type.

GROUP I - FUSILAGE

<u>CONNECTOR SERIES</u>	<u>NO. FAILED</u>	<u>TOTAL REPRESENTED</u>	<u>% FAILURES</u>
165 AN/MS, SOLDER	13	1903	0.683
69 C-5013, CRIMPED	25	12037	0.042
10-129	5	2931	0.171
2P, PCOLZ, PEOGE Solder?	17	16076	0.106
DPA, DPE Dual Panel, solder	18	10133	0.178
93 Series Rack & Panel Foka Home	1	6251	0.016
2897	3		
64 26500, Crimped	3	38673	0.008
67 9015 A, Solder	1	25177	0.004
MS50 Burndy	1		

EXHIBIT VI

Relative failure mode percentages were determined by aligning failure modes to major environmental groups. The attached sample sheet shows how these were assembled for each of the eight environmental areas.

1. TERMINATION FAILURES

- a) Defective Pins - 5
- b) Broken Wires -- 7
- c) Bare Wires
- d) Dry Joints
- e) Loose Lead
- f) Loose Pin
- g) Pins Pushed Back +3

TOTAL - 15

17%

2. IMPROPERLY SEATED - 12

- a) Loose - 24
- b) Not Installed
- c) Disconnected - 1

TOTAL - 37

43%

3. CONTAMINATED - 9

- a) High Resistance - 3
- b) Moisture - 6
- c) Dirt - 1
- d) Short - 3

TOTAL - 23

26%

3. CHANGE OF REPAIR - 8

- a) Broken Body - 3
- b) Maintenance Error - 1

TOTAL - 12

14%

6. NOT KNOWN

87

EXHIBIT VII

The tables produced in Exhibit VI were then totally correlated with the environmental areas to come out with the total number of failures by major failure modes.

RELATIVE FAILURE PERCENTAGES AMONG MAJOR FAILURE MODES

Environmental Group	Termination Failures	% of Total	Improperly Seated	% of Total	Contaminated	% of Total	Change or Repair	% of Total	Not Known	% of Total
	A B C D E F G		A B C		A B C D		A B			
I) Fuselage, Tail	5 7 3	17	24 1 12	43	3 6 1 4 9	26	3 1 8	14		0
II) Landing Gear	2 9 1	57	1	5	2 2	19	1	5	3	14
III) Engine Nacelle	2 16 1 1 1 1 1	30	13 1 2	21	3 5 1 1 12	29	3 1 8	16	3	4
IV) Engine Start Connectors	2 5	23	4 1 2 3	33	3	10	5	17	5	17
V) Engine Nose Dome Conn.	10 1	55	1	5	3	15	5	25		0
VI) Rear Engine Firewall			4	16	1 16	68	4	16		0
VII) Nacelle Strut Firewall	4 1 1	17	5 2 1	23	1 14	43	1 4	14	1	3
VIII) Nacelle Strut, Wings, Wheel Wells	2	5	13	35	9 3 1 5	49	3 1	11		0
Sub-Totals	15 50 1 1 2 2 5		65 2 5 18		7 22 5 7 64		10 2 36		12	
Totals	76		90		105		48		12	

EXHIBIT VIII

It was at this point that a choice based on performance and design parameters was made to determine which military specification (MIL-C-5015, MIL-C-26482, and MIL-C-26500) the connectors most nearly resembled in environmental characteristics.

Following this designation, the failure rate in both hours and cycles was determined for each manufacturer's series type.

The attached sample sheet shows how the connector manufacturer's series type was grouped for each environmental area under the appropriate military specification. Then the formula was set up with the number of failures, number of hours for each aircraft, and the number of aircraft involved. Thus, the failure rate per millions of hours was determined for each military specification type.

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Group I - Fuselage & Tail

HOURS 720-100,571 hrs.
707-336,696 hrs.
437,267

CYCLES 720-44,374
707-148,555
192,929

MILC-5015D
Amphenol 165

$$F.R.^{**} = \frac{13 \times 10^6}{100,571 \times 11 + 336,696 \times 11} = \frac{13 \times 10^6}{4,809,937} = 2.70 F/10^6 \text{ hrs.}$$

$$F.R. = \frac{13 \times 10^6}{44,374 \times 11 + 148,555 \times 11} = \frac{13 \times 10^6}{2,122,219} = 6.13 F/10^6 \text{ cycles}$$

Amphenol 69

$$F.R. = \frac{5 \times 10^6}{100,571 \times 5 + 336,696 \times 89} = \frac{5 \times 10^6}{30,468,799} = 0.164 F/10^6 \text{ hrs.}$$

$$F.R. = \frac{5 \times 10^6}{44,374 \times 5 + 148,555 \times 89} = \frac{5 \times 10^6}{13,443,265} = 0.372 F/10^6 \text{ cycles}$$

MFR. 1-Type 1

$$F.R. = \frac{5 \times 10^6}{100,571 \times 50 + 336,696 \times 7} = \frac{5 \times 10^6}{7,385,422} = 0.677 F/10^6 \text{ hrs.}$$

$$F.R. = \frac{5 \times 10^6}{44,374 \times 50 + 148,555 \times 7} = \frac{5 \times 10^6}{3,258,585} = 1.534 F/10^6 \text{ cycles}$$

MILC-26500
Amphenol 84

$$F.R. = \frac{3 \times 10^6}{100,571 \times 99 + 336,696 \times 261} = \frac{3 \times 10^6}{97,834,185} = 0.031 F/10^6 \text{ hrs.}$$

$$F.R. = \frac{3 \times 10^6}{44,374 \times 99 + 148,555 \times 261} = \frac{3 \times 10^6}{43,165,881} = 0.069 F/10^6 \text{ cycles}$$

** - Failure Rate

* - Failure